BUSINESS SCHOOL
ILS2016
Information Systems Logistics and Supply Chain
6th International Conference
BORDEAUX

The ConWip Production Control System: a Literature Review

Yann Jaegler[1], Patrick Burlat[2], Samir Lamouri[1]

[1] Arts et Métiers Paritech, LAMIH UMR CNRS 8201 151 boulevard de l'Hôpital, 75013 Paris, France
[2] UMR CNRS 5600 EVS, Ecole Nationale Supérieure des Mines de Saint-Etienne, Institut Henri Fayol, 158 cours Fauriel, 42023 Saint-Etienne, France

Abstract. A growing body of literature dealing with ConWip has been observed during the past decade. Considering the current industrial challenges characterized by adaptability, product customization, shortened lead times and customer satisfaction, ConWip appears to be an effective and adapted production control system for manufacturers. Given this context, this paper aims to update the previous literature review about ConWip that was made in 2003 and to provide an understanding key through an original classification method. This method allows the reader to distinguish papers that concentrate on ConWip sizing, ConWip performance, ConWip environment or on the comparison of ConWip with other PCS. It also provides a reading key about the research approach. Taking these criteria into account, this paper helps to answer the following questions: how can ConWip be implemented? How can ConWip be optimized? Why and when should ConWip be used? The paper then concludes with some research avenues.

Keywords: ConWip, Literature Review, Production Control Systems.

1 Introduction

Manufacturing competiveness is more and more driven by customer satisfaction. It has become clear that product variety, short and predictable lead times, and reliable delivery times are three of the main customer expectations. In such an environment, the effectiveness of the chosen Production Control System (PCS) is a key element for a factory. Indeed, an effective PCS allows a production line to deliver the right product, at the right time, with a controlled cost. Among the existing PCS, Constant Work in Progress (ConWip) has been first described in 1990 by [1] as a pull alternative to Kanban. At this time, the first Kanban pull systems began to achieve strong results (reduced WIP level and makespan in particular) in different manufacturing areas. Nevertheless, as pointed out by [2], Kanban was designed for repetitive and stable manufacturing systems. In this context, [1] defined ConWip in order to provide a more flexible and efficient PCS for a large range of manufacturing environments, especially those that are characterized by product variety and moving demand. This approach is highly relevant taking into account that, as explained by

[3], “managing complexity can significantly improve competitiveness by simultaneously lowering costs, reducing response time, and improving customer benefits.” Moreover, [4] shows the absolute need for efficient management of product variety. If not, the related complexity would negatively impact both direct and indirect labor productivity and quality.

In this context, the paper provides a literature review about ConWip in order to compile the last research improvements. To start with a strong basis, the following paragraph describes the main characteristics of ConWip. Based on the primordial mechanism described by [5], [1] opened the way to ConWip by describing its whole methodology. Generally speaking, controlling the total amount of work on the production line by keeping it constant is the main target of ConWip. It is routed in the law defined by [6]: LITTLE’S LAW:

$$\text{Work in Process} = \text{Throughput} * \text{Makespan} \quad \textbf{(1)}$$

ConWip uses the work orders built by MRP in order to select the part numbers and the related quantities to produce. Before it is sent on a production line, an order must be associated to a ticket, which stands for an “authorization to produce”. In the event that all of the available tickets have been associated to production orders, the new orders have to wait at the beginning of the assembly line. The completion of an order at the end of the line will release the associated ticket, which will become available for a new order. This entire process is illustrated in Figure 1.

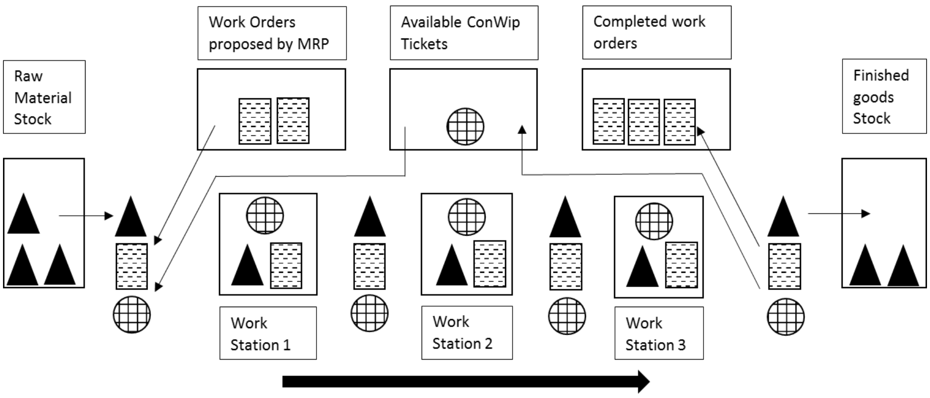

Fig. 1. Fundamentals of ConWip

This paper is structured according to the classification channels as illustrated by Figure 2. Section 2 presents the methodology. Section 3 discusses the framework for the reviewed papers. Section 4 proposes a synoptic table. To finish, Section 5 concludes by focusing on issues that would be of interest for future research.

2 Methodology

This paper aims to update the last literature review about ConWip, which was written by [7] in 2003.

This review was accomplished by searching through all of the production control systems literature that involves ConWip, with a special focus on papers that were published after 2003. The search for related publications was conducted mainly as a structured keyword search of the following terms: ConWip, modified ConWip, production control system, review, push/pull. Major databases were used to search for related papers, such as those provided by major publishers, Elsevier (www.sciencedirect.com), Emerald (www.emeraldinsight.com), Springer (www.springerlink.com), Wiley (www.wiley.com) or library services (e.g., Ebsco www.ebsco.com; Scopus www. scopus.com). Taking these delimitations into account, a first selection of papers was identified as dealing with this review topic. The final selection was based on the most influential ones in the ConWip field. Their influence has been evaluated through research on the number of citations, as shown by the search engine Google scholar, as well as their originality. We selected highly cited papers compared to less cited papers, and also took into account the most original or most recent ones. Therefore, they represent a cornerstone to the upcoming study, as they are considered the most influential academic works.

The chosen methodology consists of classifying the research about ConWip, mainly conducted after 2003, according to four channels. The four channels have been chosen so that this article provides a clear reading grid to answer four fundamental questions about ConWip: how can it be dimensioned and sized, how does it work depending on the context of its implementation, can ConWip be chosen from other PCSs, and which methodologies have been used in the different research about ConWip?

3 Classification of the research articles

3.1 How can ConWip be dimensioned and sized?

According to [1], [8] and [9] a ConWip system is sized thanks to three major characteristics: the card count, the lot sizing and the targeted makespan or throughput depending on the decision maker point of view as synthetized by Figure 2. As shown by different studies, the implementation of a ConWip system is as characterized by two minor criteria: the number of loops ([10]) and the chosen visual management ([11]) which are implemented on the production line.

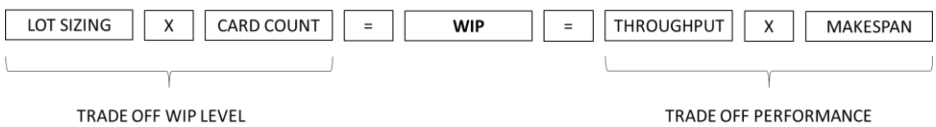

Fig. 2. Implementation of ConWip

3.2 How does ConWip work depending on the context of its implementation?

Even though ConWip has been designed as a nimble alternative to former PCS [1], it is interesting to note that the authors mainly decide to consider ConWip in a specific environment. Some papers pay attention to ConWip in an industrial environment characterized by its “make to” model or its type of shop as illustrated by Figure 3. This distinction has been chosen according to the fundamental study about production planning and control proposed by [12] in 2004. Moreover, a few articles deal with ConWip applied in non-industrial contexts.

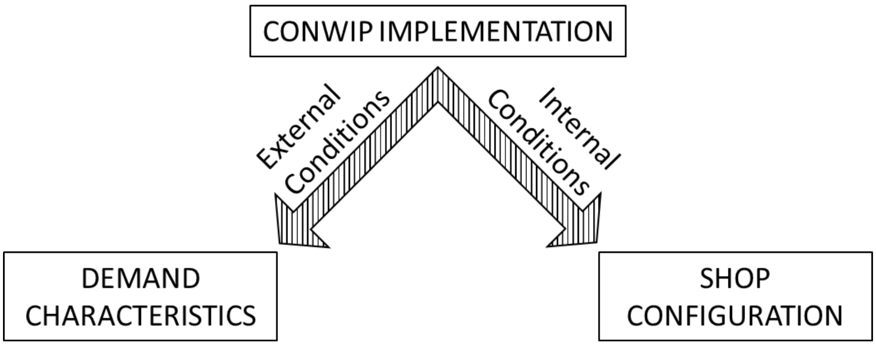

Fig. 3. ConWip Environmental Factors

3.3 How to choose between ConWip and other PCSs

ConWip was originally developed to erase some weaknesses of former PCS [1], which explains the observation made by [7]: a large number of papers have been dedicated to comparing ConWip and other PCS. This approach can provide a useful decision support system for manufacturers.

3.4 Which methodologies have been used in the different research about ConWip?

Taking into account the papers (synthetized in Table 1) that are referenced in this article, it appears that simulation is the most used research approach: 27 papers are totally or partially based on simulation, 14 are routed in a mathematical model, 6 describe new methodologies, 5 use industrial experience returns and 3 are state of the art. It is quite expected to find a majority of simulations for a comparison topic, since this is a better way to compare two systems in the same condition. It also makes sense to use a mathematical model in order to define a new concept. By the same logic, the study of ConWip in various environments should obviously lead to industrial applications. Yet, it looks as though there is a lack of research based on industrial feedback about ConWip, which, consequently appears to be a future research topic in need of development.

4 Synoptic Table

The classification explained in the previous section provides a framework. The articles reviewed will be analysed through it.

Table 1. Overview of the referenced papers.

CC: Card Count	MTO: Make to Order	Pu: Push	MM: Mathematical Model
LS: Lot Sizing	MTS: Make to Stock	K: Kanban	MD: Method Description
T: Throughput	FS: Flowshop	MK: Modified Kanban	LR: Literature Review
M: Makespan	JS: Jobshop	MC: Modified ConWip	S: Simulation
NL: Nber of Loops	NI: Non Industrial	P: Polca	IR: Industrial Rex
		C: Cobacabana	NIR: Non Industrial Rex

Ref.	**Implementation and Sizing**			**Environment**			**ConWip Compared To**	**Research Approach**
	CC/LS	***T/W/M***	***NL***	***Demand***	***Shop Type***	***NI***		
[1]		T/M/W					Pu/K	MD/S
[6]								MM
[7]	CC	T/M/W					Pu/K/HK	LR
[8]		T/M						S
[9]	CC	T/M/W		MTS				S
[10]			X					S/IR
[12]				MTO	JS		Pu/K/Po	LR
[13]	CC							MM
[14]	CC						Pu/K	S
[15]	CC	M		MTS	FS			S/IR
[16]	CC			MTS				S
[17]	CC							S/MM
[18]	LS			MTS	FS			MM
[19]			X				Pu/C	S
[20]		T/M		MTO	JS			S/IR
[21]	CC	T/M			FS			S
[22]	CC			MTS				S
[23]				MTS			Pu/K/MCW	S
[24]				MTS	FS		K/HK	S
[25]				MTO	JS		K/Po	S
[26]				MTO			Po/MCW	S
[27]				MTS	FS		K/HK	S
[28]		M			FS			S
[29]		T/WIP			JS			MM
[30]							C	MD
[31]	CC				JS		C	S
[32]						X		MD/NIR
[33]						X		NIR
[34]		T					Pu/K	MM/MD
[35]					FS		Pu/K/MCW	S
[36]							Pu/K	MM
[37]							K/HK	MM
[38]							K/HK	MM
[39]				MTS			HK	MM
[40]					FS		MCW	S
[41]							K/MCW	LR

[42]						Po	MD
[43]	LS						MM/S
[44]		T			FS		MM
[45]		W/T			FS		S
[46]		W		MTS	FS		MM/S
[47]		T			JS	Pu	S
[48]				MTS	FS	Pu	S
[49]		W			FS	Pu/K	S
[50]							IR
[51]				MTO	JS		S
[52]		M		MTS	FS		MM
[53]						K	MM
[54]					FS	HK	S
[55]					JS		S
[56]		M/WIP					IR
[57]						Po	MD/IR
[58]						Po	S
[60]		W/T		MTS	FS	K	S
[61]				MTS	FS		MM
[62]	CC	M			FS		MM
[63]	CC	T		MTS/O			S
[64]		W		MTS	FS	Pu/HK	S
[65]		W/T			JS		MM
[66]		W/T			FS	K	S
[67]	CC	W/T			FS		MM
[68]			X				S

5 Conclusion

At the present time, considering the globalized market and customer behavior, manufacturers absolutely need to stick to and even anticipate client expectations. In view of this trend, make to order productions can be considered as the way of the future for industry, as shown by [12]. Furthermore, [59] illustrates that efficient and customized jobshop organizations are tailored to the growing demand for customized, and even specific, products. In this context, three conclusions dealing with potential research avenues can be drawn from this literature review.

Firstly, decision tools about the better PCS choice in a given context is a real need and therefore is a very relevant topic. Nevertheless, ConWip has been widely compared to all existing PCS; this set of studies supplies a relevant and complete database for anyone who needs to choose between the existing PCSs. In this context, it appears as though a comparison between ConWip and other systems is not a major research avenue.

Secondly, it appears that a large majority of the literature about ConWip is dedicated to make to stock (MTS) environments and to flowshop production areas. This state of fact is probably routed in the common idea explained by [41] which promotes the fact that ConWip was "originally designed for manufacturing with constant product routings, similar processing times, minimal set-ups and linear process flow." This article shows, however, that few papers tried to demonstrate the ability of ConWip to manage MTO industry with plants designed as jobshops.

Considering the minimal attention paid to this specific topic, it appears as though ConWip processing in a jobshop and MTO industry is a relevant research avenue.

Thirdly, the last section of this paper shows a lack of author interest in the industrial experience return with ConWip. That is the reason why studying ConWip in an applied production context needs to be underlined as a third main future research avenue to conduct.

References

1. Spearman, M. L., Woodruff, D. L., & Hopp, W. J. (1990). CONWIP: a pull alternative to kanban. The International Journal of Production Research, 28(5), 879-894.
2. Hall, R. (1981). Driving the Productivity Machine: Production, Planning and Control in Japan American Production and Inventory Control Society. Falls Church, Virginia.
3. Child, P., Diederichs, R., Sanders, F. H., & Wisniowski, S. (1991). SMR forum: The management of complexity. MIT Sloan Management Review, 33(1), 73.
4. MacDuffie, J. P., Sethuraman, K., & Fisher, M. L. (1996). Product variety and manufacturing performance: evidence from the international automotive assembly plant study. Management Science, 42(3), 350-369.
5. Jackson, J. R. (1963). Jobshop-like queueing systems. Management science, 10(1), 131-142.
6. Little, J. D. (1961). A proof for the queuing formula: L= λ W. Operations research, 9(3), 383-387.
7. Framinan, J. M., González, P. L., & Ruiz-Usano, R. (2003). The CONWIP production control system: review and research issues. Production Planning & Control, 14(3), 255-265.
8. Hopp, W. J., & Spearman, M. L. (1991). Throughput of a constant work in process manufacturing line subject to failures. THE INTERNATIONAL JOURNAL OF PRODUCTION RESEARCH, 29(3), 635-655.
9. Hopp, W. J., & Roof, M. L. (1998). Setting WIP levels with statistical throughput control (STC) in CONWIP production lines. International Journal of Production Research, 36(4), 867-882.
10. Ip, W. H., Huang, M., Yung, K. L., Wang, D., & Wang, X. (2007). CONWIP based control of a lamp assembly production line. Journal of Intelligent Manufacturing, 18(2), 261-271.
11. Patrick Burlat, Techniques de l'Ingénieur
12. Stevenson*, M., Hendry, L. C., & Kingsman†, B. G. (2005). A review of production planning and control: the applicability of key concepts to the make-to-order industry. International journal of production research, 43(5), 869-898.
13. Hopp, W., & Spearman, M. (1996). Factory physics: foundations of factory management. InvinIMcGraw Hill, Chicago, IL.
14. Marek, R. P., Elkins, D. A., & Smith, D. R. (2001, December). Manufacturing controls: understanding the fundamentals of Kanban and CONWIP pull systems using simulation. In Proceedings of the 33nd conference on Winter simulation (pp. 921-929). IEEE Computer Society.
15. Pergher, I., & Vaccaro, G. L. R. (2014). Work in process level definition: a method based on computer simulation and electre tri. Production, 24(3), 536-547.
16. Tardif, V., & Maaseidvaag, L. (2001). An adaptive approach to controlling kanban systems. European Journal of Operational Research, 132(2), 411-424.
17. Belisário, L. S., & Pierreval, H. (2015). Using genetic programming and simulation to learn how to dynamically adapt the number of cards in reactive pull systems. Expert Systems with Applications, 42(6), 3129-3141.
18. Zhang, W., & Chen, M. (2001). A mathematical programming model for production planning using CONWIP. International Journal of Production Research, 39(12), 2723-2734.

19. Eng, C. K., & Sin, L. K. (2013). CONWIP based control of a semiconductor end of line assembly. Procedia Engineering, 53, 607-615.
20. Romagnoli, G. (2015). Design and simulation of CONWIP in the complex flexible job shop of a Make-To-Order manufacturing firm. International Journal of Industrial Engineering Computations, 6(1), 117-134.
21. Herer, Y. T., & Shalom, L. (2000). The Kanban assignment problem–A non-integral approach. European Journal of Operational Research, 120(2), 260-276.
22. Ryan*, S. M., & Vorasayan, J. (2005). Allocating work in process in a multiple-product CONWIP system with lost sales. International Journal of Production Research, 43(2), 223-246.
23. Takahashi, K., & Hirotani, D. (2005). Comparing CONWIP, synchronized CONWIP, and Kanban in complex supply chains. International journal of production Economics, 93, 25-40.
24. Lavoie, P., Gharbi, A., & Kenne, J. P. (2010). A comparative study of pull control mechanisms for unreliable homogenous transfer lines. International Journal of Production Economics, 124(1), 241-251.
25. Harrod, S., & Kanet, J. J. (2013). Applying work flow control in make-to-order job shops. International Journal of Production Economics, 143(2), 620-626.
26. Germs, R., & Riezebos, J. (2010). Workload balancing capability of pull systems in MTO production. International Journal of Production Research,48(8), 2345-2360.
27. Bonvik, A. M., Couch, C. E., & Gershwin, S. B. (1997). A comparison of production-line control mechanisms. International journal of production research, 35(3), 789-804.
28. Framinan, J. M., Ruiz-Usano, R., & Leisten, R. (2001). Sequencing CONWIP flow-shops: analysis and heuristics. International Journal of Production Research, 39(12), 2735-2749.
29. Ryan, S. M., Baynat, B., & Choobineh, F. F. (2000). Determining inventory levels in a CONWIP controlled job shop. IIE transactions, 32(2), 105-114.
30. Land, M. J. (2009). Cobacabana (control of balance by card-based navigation): A card-based system for job shop control. International Journal of Production Economics, 117(1), 97-103.
31. Thürer, M., Land, M. J., & Stevenson, M. (2014). Card-based workload control for job shops: Improving COBACABANA. International Journal of Production Economics, 147, 180-188.
32. Dallasega, P., Rauch, E., & Matt, D. T. (2015). Sustainability in the supply chain through synchronization of demand and supply in ETO-companies. Procedia CIRP, 29, 215-220.
33. Crop, F., Lacornerie, T., Mirabel, X., & Lartigau, E. (2015). Workflow optimization for robotic stereotactic radiotherapy treatments: Application of Constant Work In Progress workflow. Operations Research for Health Care, 6, 18-22.
34. Spearman, M. L., & Zazanis, M. A. (1992). Push and pull production systems: issues and comparisons. Operations research, 40(3), 521-532.
35. Prakash, J., & Feng, C. J. (2011). A comparison of push and pull production controls under machine breakdown. International Journal of Business Science and Applied Management, 6(3), 58-70
36. Gong, Q., Yang, Y., & Wang, S. (2014). Information and decision-making delays in MRP, KANBAN, and CONWIP. International Journal of Production Economics, 156, 208-213.
37. Baynat, B., Dallery, Y., Mascolo, M. D., & Frein, Y. (2001). A multi-class approximation technique for the analysis of kanban-like control systems. International Journal of production research, 39(2), 307-328.
38. Baynat, B., Buzacott, J. A., & Dallery, Y. (2002). Multiproduct kanban-like control systems. International Journal of Production Research, 40(16), 4225-4255.
39. Korugan, A., & Gupta, S. M. (2014). An adaptive CONWIP mechanism for hybrid production systems. The International Journal of Advanced Manufacturing Technology, 74(5-8), 715-727.

40. Onyeocha, C. E., Khoury, J., & Geraghty, J. (2013, December). A comparison of kanban-like control strategies in a multi-product manufacturing system under erratic demand. In Proceedings of the 2013 Winter Simulation Conference: Simulation: Making Decisions in a Complex World (pp. 2730-2741). IEEE Press.
41. Prakash, J., & Chin, J. F. (2014). Modified CONWIP systems: a review and classification. Production Planning & Control, (ahead-of-print), 1-12.
42. Suri, R. (1998). Quick response manufacturing: a companywide approach to reducing lead times. Productivity Press.
43. Satyam, K., & Krishnamurthy, A. (2013). Performance analysis of CONWIP systems with batch size constraints. Annals of Operations Research, 209(1), 85-114.
44. Parvin, H., Van Oyen, M. P., Pandelis, D. G., Williams, D. P., & Lee, J. (2012). Fixed task zone chaining: worker coordination and zone design for inexpensive cross-training in serial CONWIP lines. IIE Transactions, 44(10), 894-914.
45. Helber, S., Schimmelpfeng, K., & Stolletz, R. (2011). Setting inventory levels of CONWIP flow lines via linear programming. BuR-Business Research, 4(1), 98-115.
46. Mhada, F., & Malhamé, R. (2011). Approximate performance analysis of CONWIP disciplines in unreliable non homogeneous transfer lines. Annals of Operations Research, 182(1), 213-233.
47. Li, J. W. (2010). Simulation study of coordinating layout change and quality improvement for adapting job shop manufacturing to CONWIP control. International Journal of Production Research, 48(3), 879-900.
48. Bahaji, N., & Kuhl, M. E. (2008). A simulation study of new multi-objective composite dispatching rules, CONWIP, and push lot release in semiconductor fabrication. International Journal of Production Research, 46(14), 3801-3824.
49. Jodlbauer, H., & Huber, A. (2008). Service-level performance of MRP, kanban, CONWIP and DBR due to parameter stability and environmental robustness. International Journal of Production Research, 46(8), 2179-2195.
50. Gastermann, B., Stopper, M., Luftensteiner, F., & Katalinic, B. (2014). Implementation of a Software Prototype with ConWIP Characteristics for Production Planning and Stock Management. Procedia Engineering, 69, 423-432.
51. Bertolini, Romagnoli, Zammori. Assessing performance of Work Load Control in High Variety Low Volumes MTO job shops: a simulative analysis. 2015
52. Bonvik, A. M., Dallery, Y., & Gershwin, S. B. (2000). Approximate analysis of production systems operated by a CONWIP/finite buffer hybrid control policy. International Journal of Production Research, 38(13), 2845-2869.
53. Giard, V., & Mendy-Bilek, G. (2006). Production à flux tirés dans une chaîne logistique. Logistique & Management, 14(2), 15-28.
54. Onyeocha, C. E., Wang, J., Khoury, J., & Geraghty, J. (2015). A comparison of HK-CONWIP and BK-CONWIP control strategies in a multi-product manufacturing system. Operations Research Perspectives, 2, 137-149.
55. Papadopoulou, T. C. (2013). Application of lean scheduling and production control in non-repetitive manufacturing systems using intelligent agent decision support (Doctoral dissertation, Brunel University School of Engineering and Design PhD Theses).
56. Srinivasan, M. M., Ebbing, S. J., & Swearingen, A. T. (2003). Woodward Aircraft Engine Systems sets work-in-process levels for high-variety, low-volume products. Interfaces, 33(4), 61-69.
57. Suri, R., & Krishnamurthy, A. (2003). How to Plan and Implement POLCA–A Material Control System for High Variety or Custom-Engineered Products.Center for Quick Response management Technical Report.
58. Ziengs, N., Riezebos, J., & Germs, R. (2012). Placement of effective work-in-progress limits in route-specific unit-based pull systems. International Journal of Production Research, 50(16), 4358-4371.

59. Ounnar, F., & Pujo, P. (2012). Pull control for Job Shop: Holonic Manufacturing System approach using multicriteria decision-making. Journal of Intelligent Manufacturing, 23(1), 141-153.
60. Y. Khojasteh-Ghamari, A performance comparison between Kanban and CONWIP controlled assembly systems, J. Intell. Manuf. 20 (2009) 751-760.
61. C.W. Park, H.S. Lee, Performance evaluation of a multi-product CONWIP assembly system with correlated external demands, International Journal of Production Economics 144 (2013) 334-344.
62. S. Ajorlou, I. Shams Artificial bee colony algorithm for CONWIP production control system in a multi-product multi-manufacturing process manufacturing environment, J Intell Manuf, 24 (2013), pp. 1145–1156
63. Framinan et al., 2006 J.M. Framinan, P.L. González, R. Ruiz-Usano Dynamic card controlling in a CONWIP system, International Journal of Production Economics, 99 (2006), pp. 102–116
64. Geraghty and Heavey, 2004. J. Geraghty, C. Heavey, A comparison of hybrid push/pull and CONWIP/pull production inventory control policies, International Journal of Production Economics, 91 (2004), pp. 75–90
65. K. Satyam, A. Krishnamurthy, Performance evaluation of a multi-product system under CONWIP control, IIE Transactions 40 (2008) 252-264.
66. J.A. Pettersen, A. Segerstedt, Restricted work-in-process: a study of differences between Kanban and CONWIP, Int J Prod Econ, 118 (2009), pp. 199–207
67. Braglia, M., Frosolini, M., Gabbrielli, R., & Zammori, F. (2011). CONWIP card setting in a flow-shop system with a batch production machine. International Journal of Industrial Engineering Computations, 2(1), 1-18.
68. G. Huang, J. Chen, X. Wang, Y. Shi, A simulation study of CONWIP assembly with multi-loop in mass production, multi-products and low volume and OKP environments, Int J Prod Res (2014)